

(19)



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(11)

EP 1 630 996 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

01.03.2006 Bulletin 2006/09

(51) Int Cl.:

H04L 7/027^(2006.01)**H04N 5/455^(2006.01)**(21) Application number: **05107782.4**(22) Date of filing: **24.08.2005**

(84) Designated Contracting States:

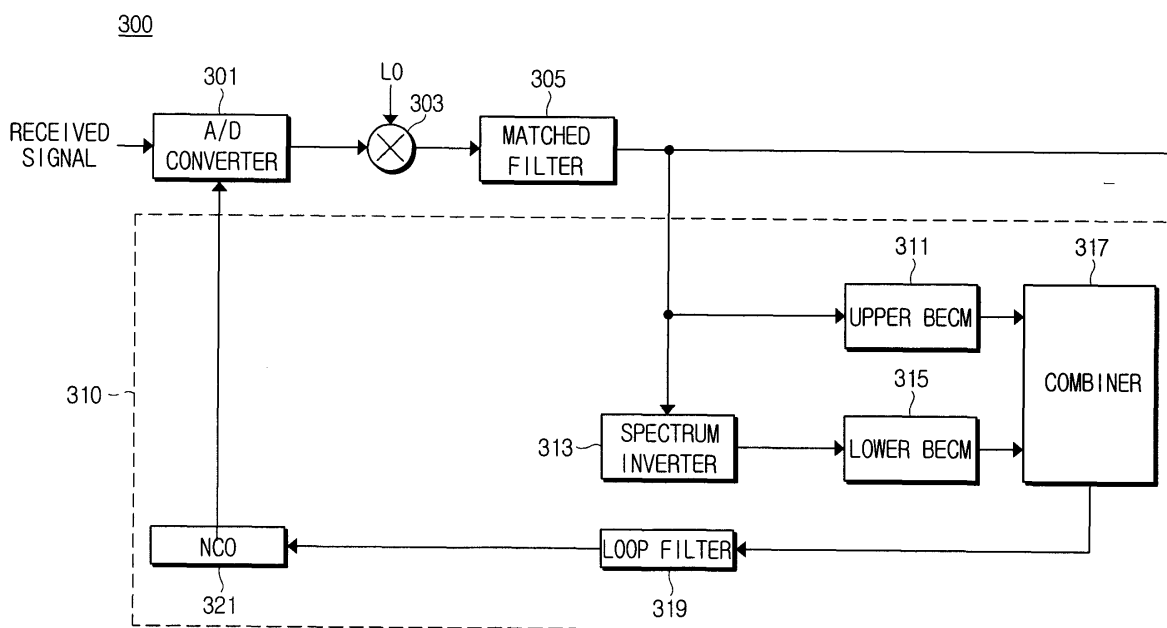
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR

Designated Extension States:

AL BA HR MK YU(30) Priority: **26.08.2004 KR 2004067499**(71) Applicant: **SAMSUNG ELECTRONICS CO., LTD.****Suwon-si,****Gyeonggi-do 442-742 (KR)**(72) Inventor: **LEE, Dong-hoon,****244-803, Hwanggol-maeul Ssangyong****Suwon-si,****Gyeonggi-do (KR)**(74) Representative: **Geary, Stuart Lloyd et al****Venner Shipley LLP****20 Little Britain****London EC1A 7DH (GB)**(54) **Vestigial sideband receiver**

(57) A symbol timing recovery apparatus used with a VSB-type receiver and a method of the same. In order for the symbol timing recovery, error information is generated and used utilizing a band edge component maximization (BECM) of a frequency band as well as an upper frequency band. Therefore, the symbol timing recovery can be more effectively achieved even when the upper

frequency band is damaged due to multi-path components. Also, efficiency of the overall timing recovery can be improved by using the lower frequency band as well as the upper frequency band of the received signal in performing the symbol timing recovery. As a result, deterioration of the receiving system including the symbol timing recovery apparatus can be prevented.

FIG. 3**EP 1 630 996 A2**

Description

[0001] The present invention relates to a symbol recovery apparatus for use with a vestigial sideband receiver.

[0002] When demodulating data in a Vestigial Side Band (VSB) receiver, the same clock as is used in a transmitter should be generated. This process is called 'Symbol Timing Recovery.'

[0003] The symbol timing recovery may be performed by a method using a data segment synchronizing signal which is regularly inserted during data transmission by the transmitter. Alternatively, a band edge component maximization (BECM) algorithm may be used.

[0004] The BECM algorithm recovers symbol timing by reading phase information of a received signal using a spectral line which is a harmonic signal of an upper frequency band signal of a VSB-modulated received signal. A Gardener algorithm is a typical example of the BECM algorithm.

[0005] Figure 1 is a block diagram of a symbol timing recovery apparatus according to a conventional BECM algorithm.

[0006] Referring to FIG. 1, the conventional recovery apparatus 100 comprises an analogue-to-digital converter (ADC) 101, a mixer 103, a matched filter 104, a BECM 200, a loop filter 109, and a numerically controlled oscillator (NCO) 111.

[0007] The VSB-modulated received signal is converted to a digital signal by the ADC 101. The mixer 103 receives a second NCO signal and converts the digitised VSB signal to a base-band signal.

[0008] The base-band signal is then fed to the matched filter 105 and the BECM 200 then outputs error information of a symbol clock. The loop filter 109 outputs an NCO controlling voltage corresponding to the error information, which is used to adjust the symbol clock input to the ADC 101.

[0009] Figure 2 is a block diagram illustrating the BECM of Figure 1. Referring to Figure 2, the BECM 200 comprises a pre filter 201, a non-linear device 203, a symbol tone extractor 205, and a phase detector 207.

[0010] The pre filter 201 (which may be a high pass filter) receives the VSB-modulated signal, which has passed through the matched filter 105 (Figure 1), and high-pass filters so that only the upper frequency band signals are passed through the filter. The non-linear device 203 generates harmonic components of the signal output from the pre filter 201. The symbol tone extractor 205 extracts symbol tone from the plurality of harmonics generated by the non-linear device 203. The symbol tone refers to a component having the same frequency as the clock used in the transmitter. The phase detector 207 outputs the error information of a symbol clock (or, symbol phase), which is the information on the error between a preset reference symbol phase and a phase of the extracted symbol tone.

[0011] As aforementioned, the symbol timing recovery

apparatus using the conventional BECM algorithm uses only the upper frequency band of the received VSB-modulated signals.

[0012] However, when the received VSB-modulated signals are distorted on the transmission channel and the signals in the upper frequency band are seriously damaged, performance of the symbol timing recovery apparatus is considerably deteriorated. The damage of the upper frequency band signals increases especially in an environment having lots of multi-path components, and this causes deterioration of receiving performance.

[0013] Accordingly, the present invention provides a symbol timing recovery apparatus for a vestigial side band (VSB)-type receiver, which is capable of efficiently performing symbol timing recovery by using both upper and lower frequency bands of received VSB signals for the symbol timing recovery, even when the upper frequency band of the received VSB signals are damaged due to multi-path environment of a channel, and a method for the same.

[0014] According to a first aspect of the present invention, there is provided a symbol recovery apparatus for a Vestigial Sideband (VSB) receiver comprising an analogue to digital converter for sampling an input VSB signal; an oscillator whose output signal is configured to be a sampling clock for the analogue to digital converter and is dependent upon a control signal, and means for generating the control signal in accordance with a band edge component maximisation technique, wherein the means is configured to generate the control signal in accordance with a frequency spectrum transposed representation of the sampled VSB signal at baseband.

[0015] Additional advantageous and/or preferred features are set forth in claims 2 to 4 appended hereto.

[0016] Additional aspects and advantages of the present invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the present invention.

[0017] The foregoing and/or other aspects and advantages of the present general inventive concept are achieved by providing a symbol timing recovery apparatus used with a VSB-type receiver, the apparatus including an analog-to-digital converter (ADC) to receive a signal which is modulated by a vestigial side band (VSB) scheme and to digitalize the received signal using a pre-determined sampling clock; a multiplier to transit the digitalized VSB signal to a baseband; a spectrum inverter to invert a spectrum by exchanging upper and lower frequency bands of the baseband VSB signal received from the multiplier; a lower band edge component maximization (BECM) to perform a BECM algorithm with respect to the inverted baseband VSB signal, thereby generating lower error information which is the information on the error between a symbol phase of the received VSB-modulated signal and a preset reference symbol phase; a loop filter to filter the lower error information of the lower BECM to output a lower band signal; and a numerically

controlled oscillator (NCO) to change a predetermined sampling clock according to the lower band signal from the loop filter.

[0018] The symbol timing recovery apparatus may further include an upper BECM to perform the BECM algorithm directly with respect to the baseband VSB signal received from the multiplier, thereby generating upper error information which is the information on the error between a symbol phase of the received VSB-modulated signal and a preset reference symbol phase; and a combiner to multiply the upper and the lower error information of the upper and the lower BECMs by predetermined weights, respectively, and to output to the loop filter final error information obtained by adding the multiplied values.

[0019] The predetermined weights vary according to reliability of the upper and the lower error information according to a channel state.

[0020] The spectrum inverter detects and deletes a pilot signal of the VSB signal before inverting the spectrum by exchanging the upper and the lower bands of the frequency spectrum of the baseband VSB signal.

[0021] The symbol timing recovery apparatus may further include a matched filter provided in front of the spectrum inverter to filter off the baseband VSB signal so as to increase signal-to-noise ratio.

[0022] The VSB-modulated signal is an American digital broadcasting signal of an advanced television system committee (ATSC) standard.

[0023] A receiver using a symbol timing recovery apparatus for a VSB-type receiver according to an embodiment of the present general inventive concept, receives a VSB-modulated signal by performing symbol timing recovery of a received VSB signal.

[0024] The foregoing and/or other aspects and advantages of the present general inventive concept are also achieved by providing a method of symbol timing recovery for a VSB-type receiver, the method including receiving a VSB-modulated signal and digitalizing the signal using a predetermined sampling clock; transiting the digitalized VSB signal to a baseband; inverting a spectrum by exchanging upper and lower frequency bands of the baseband VSB signal; generating lower error information which is the information on the error between a symbol phase of the received signal and a preset reference symbol phase, by performing BECM algorithm with respect to the spectrum-inverted signal; and changing the predetermined sampling clock according to the lower error information.

[0025] The method may further include performing the BECM algorithm directly with respect to the baseband VSB signal in the transiting operation, thereby generating upper error information which is the information on the error between a symbol phase of the received VSB-modulated signal and a preset reference symbol phase; and multiplying the upper and the lower error information by predetermined weights, respectively, and outputting final error information obtained by adding the multiplied values

to the sampling clock changing operation.

[0026] The predetermined weights vary according to reliability of the upper and the lower error information according to a channel state.

[0027] The inverting operation detects and deletes a pilot signal of the VSB signal before inverting the spectrum by exchanging the upper and the lower bands of the frequency spectrum of the baseband VSB signal.

[0028] The method may further include filtering off the baseband VSB signal before the inverting operation, so as to increase signal-to-noise ratio.

[0029] The foregoing and/or other aspects and advantages of the present general inventive concept are also achieved by providing a symbol timing recovery apparatus used with a VSB-type receiver, the apparatus including a multiplier to transit a digitalized signal modulated by a vestigial side band (VSB) scheme signal to a baseband, and a timing recovery unit to invert a spectrum by exchanging upper and lower frequency bands of the baseband VSB signal received from the multiplier, to perform a lower band edge component maximization (BECM) algorithm with respect to the inverted baseband VSB signal, thereby generating lower error information which is the information on the error between a symbol phase of the received VSB-modulated signal and a preset reference symbol phase, to filter the lower error information of the lower BECM to output a lower band signal, and to change a predetermined sampling clock according to the lower band signal from the loop filter.

[0030] The foregoing and/or other aspects and advantages of the present general inventive concept are also achieved by providing a method of symbol timing recovery for a VSB-type receiver, the method including transiting a digitalized VSB-modulated signal to a baseband, inverting a spectrum by exchanging upper and lower frequency bands of the baseband VSB signal, detecting error information of respective symbol clocks from the baseband VSB signals of the lower frequency band and the upper frequency band, and combining the error information detected to perform symbol timing recovery.

[0031] Embodiments of the present invention will now be described by way of example only and with reference to Figures 3 to 5 of the accompanying drawings, in which:

Figure 1 is a block diagram of a symbol timing recovery apparatus according to a conventional band edge component maximization (BECM) algorithm; Figure 2 is a block diagram illustrating an example of a BECM of Figure 1;

Figure 3 is a block diagram of a symbol timing recovery apparatus used with a vestigial side band (VSB)-type receiver, according to an embodiment of the present invention;

Figure 4 is a graph illustrating a frequency spectrum of a baseband VSB signal for input to the symbol timing recovery apparatus according to an embodiment of the present invention; and

Figure 5 is a flowchart illustrating operations of the

symbol timing recovery apparatus for a VSB-type receiver, according to an embodiment of the present invention.

[0032] In the following description, same drawing reference numerals are used for the same elements even in different drawings. The matters defined in the description such as a detailed construction and elements are nothing but the ones provided to assist in a comprehensive understanding of the general inventive concept. Thus, it is apparent that the present general inventive concept can be carried out without those defined matters. Also, well-known functions or constructions are not described in detail since they would obscure the general inventive concept in unnecessary detail.

[0033] Referring to Figure 3, the symbol timing recovery apparatus 300 includes an analogue-to-digital converter (ADC) 301, a multiplier 303, a matched filter 305, and a timing recovery unit 310.

[0034] The symbol timing recovery apparatus 300 may be applied as an apparatus which receives and demodulates a signal modulated by vestigial side band (VSB) scheme (hereinafter, referred to as 'VSB signal').

[0035] The symbol timing recovery apparatus 300 may be employed by a receiver which receives an American digital broadcasting signal using 8-level VSB scheme of an Advanced Television System Committee (ATSC) standard. Hereinbelow, a description will be made with respect to the receiver receiving the American digital broadcasting signal of the 8-level VSB scheme.

[0036] The ADC 301 digitises a received VSB signal using a clock recovered by the symbol timing recovery apparatus 300. The multiplier 303 converts the digitised signal to a baseband signal of a by receiving a clock from a local oscillator (LO).

[0037] The baseband VSB signal is output through the matched filter 305. The output signal may be input to and equalised by an equaliser (not shown).

[0038] The timing recovery unit 310 includes an upper band edge component maximization (BECM) 311, a spectrum inverter 313, a lower BECM 315, a combiner 317, a loop filter 319, and a numerically controlled oscillator (NCO) 321.

[0039] The timing recovery unit 310 generates a clock having the same phase as the clock which is used to generate the VSB signal in the transmitter (not shown) when sampling the received VSB signal.

[0040] To this end, the timing recovery unit 310 receives the digitised base band VSB signal (hereinafter, referred to as 'base band VSB signal'). The timing recovery unit 310 receives the signal which has passed through the matched filter 305.

[0041] The timing recovery unit 310 detects the error information of the respective symbol clocks from the baseband VSB signals of the lower frequency band, as well as those of the upper frequency band. By combining the error information, the timing recovery unit 310 is able to effectively perform the symbol timing recovery even

when the upper frequency band of the VSB signals is damaged on the transmission channel.

[0042] A graph (a) of Figure 4 illustrates a frequency spectrum of the baseband VSB signal. The bandwidth of the received signal is approximately 6MHz, a section 'a' denotes the upper frequency band and a section 'b' denotes a pilot signal.

[0043] The baseband VSB signal of the graph (a) is input to the upper BECM 311 to generate the error information of the symbol clock from the upper frequency band of the baseband VSB signal. The signal of the graph (b) is input to the lower BECM 315 to generate the error information of the symbol clock from the lower frequency band of the baseband VSB signal.

[0044] The upper and the lower BECMs 311 and 315 generate the error information of the symbol clock using the BECM algorithm, typically a Gardner algorithm.

[0045] The upper BECM 311 generates harmonic components of the upper frequency band signal from the frequency VSB signal and extracts the symbol tone from amongst the plurality of generated harmonic components. The symbol tone has the same phase as the symbol clock used in the transmitter (not shown). Then, the upper BECM 311 compares the symbol tone with a preset reference symbol phase, thereby outputting upper error information of the symbol phase.

[0046] The spectrum inverter 313 receives the frequency VSB signal and inverts the frequency spectrum. By inverting the frequency spectrum, the upper frequency band and the lower frequency band are exchanged with each other. The output of the spectrum inverter 313 is output to the lower BECM 315.

[0047] The lower BECM 315 operates in a similar manner to the upper BECM unit 311 to output lower error information which is the information about the error between the preset reference symbol phase and the phase of the symbol tone extracted from the received lower frequency band. The signal input to the lower BECM 315 is the baseband VSB signal whose frequency spectrum is inverted. The lower frequency band of the baseband VSB signal is inverted to be in the upper frequency band and input into the lower BECM 315.

[0048] As shown in Figure 4(b), the baseband VSB signal inverted by the spectrum inverter 313 and input to the lower BECM 315 includes a pilot signal located in the upper frequency band. The lower error information output from the lower BECM 315 using the pilot signal is more reliable than the upper error information. Thus, the combiner 317 considers the influence of the pilot signal included in the inverted spectrum.

[0049] However, the pilot signal may be deleted from the signals input to the lower BECM 315. In this case, the combiner 317 may not dedicatedly consider the influence of the pilot signal.

[0050] For this reason, the pilot signal is deleted from the signals input to the lower BECM 315. The spectrum inverter 313 detects the pilot signal from the baseband VSB signal and deletes the pilot signal from the baseband

VSF signal before inverting the frequency spectrum.

[0051] The combiner 317 therefore receives and combines only the upper and the lower error information from the upper and the lower BECM 311 and 315 and outputs the combined information as 'final error information' to the loop filter 319. The combiner 317 multiplies the upper and the lower error information by appropriate weights K1 and K2, respectively, and adds the multiplied values to thereby generate the final error information.

[0052] The weights K1 and K2 may vary according to the state of the channel which distort the upper and the lower frequency bands of the received baseband VSB signals. A higher weight is given to the error information having higher reliability. Therefore, the lower error information output from the lower BECM 315, which has relatively high reliability due to the pilot signal, is usually given the higher weight.

[0053] In order to apply appropriate weights according to the state of the channel, information about the channel state is obtained in various ways. For example, the size of the signals input to the upper and the lower BECMs 311 and 315 may be used to determine the weights.

[0054] The loop filter 319 passes and outputs to the NCO 321 only the signal components of the lower band from among the final error information output from the combiner 317.

[0055] The NCO 321 changes output frequency according to the lower band signal component output from the loop filter 319, thereby changing the sampling clock of the ADC 301.

[0056] According to another embodiment of the present general inventive concept, only the spectrum inverter 313 and the lower BECM 315 are used, so that only the lower frequency band of the baseband VSB signal is used.

[0057] Referring to Figure 5, the timing recovery unit 310 receives the baseband VSB signal. The received baseband VSB signal has the frequency spectrum as shown by the graph of Figure 4 (a). The upper frequency band of the baseband VSB signal is approximately 6MHz. This is the frequency band width of the American digital broadcasting of the Advanced Television System Committee (ATSC) standard (operation S501).

[0058] The upper BECM 311 performs the BECM algorithm, thereby outputting to the combiner 317 the upper error information which is the information about the error between the symbol phase detected from the received baseband VSB signal and the preset reference symbol phase. Simultaneously, the frequency spectrum of the baseband VSB signal is inverted by the spectrum inverter 313 as shown in Figure 4 (b) and input to the lower BECM 315.

[0059] The lower BECM 315 performs the BECM algorithm, thereby detecting the symbol phase from the inverted baseband VSB signal, and outputs to the combiner 317 the lower error information which is the information about the error between the detected symbol phase and the preset reference symbol.

[0060] In another embodiment of the present invention, the pilot signal component is deleted from the inverted baseband VSB signal input to the lower BECM 315. To perform this operation, the pilot signal is detected by the spectrum inverter 313 and deleted from the baseband VSB signal (operation S503).

[0061] The generated upper and the lower error information is input to the combiner 317, and the combiner 317 multiplies the upper and the lower error information by the weights K1 and K2, respectively, and adds the multiplied values to thereby obtain the final error information (operation S505).

[0062] The loop filter 319 passes through and outputs to the NCO 321 only the signal components of the lower band among the final error information generated by the combiner 317. The NCO 321 changes its output frequency according to the lower band signal component output from the loop filter 319, thereby changing a sampling clock of the ADC 301 (operation S507).

[0063] Thus, the symbol timing recovery apparatus for a VSB-type receiver is operated using the above-described processes.

[0064] As can be appreciated from the above description, since symbol timing recovery is performed using the lower frequency band of the received VSB-modulated signal, the symbol timing recovery can be more effectively achieved even when the upper frequency band is damaged due to multi-path components. Also, efficiency of the overall timing recovery can be improved by using the lower frequency band as well as the upper frequency band of the received signal in performing the symbol timing recovery. As a result, deterioration of the receiving system including the symbol timing recovery apparatus is prevented.

Claims

1. A symbol recovery apparatus (300) for a Vestigial Sideband (VSB) receiver comprising an analogue to digital converter (301) for sampling an input VSB signal; an oscillator (321) whose output signal is configured to be a sampling clock for the analogue to digital converter (301) and is dependent upon a control signal, and means (310) for generating the control signal in accordance with a band edge component maximisation technique, wherein the means (310) is configured to generate the control signal in accordance with a frequency spectrum transposed representation of the sampled VSB signal at baseband.
2. A symbol recovery apparatus according to claim 1, wherein the means (310) is configured to generate the control signal in accordance with a transposed inverted frequency spectrum representation of the sampled VSB signal.

3. A symbol recovery apparatus according to either one of claims 1 or 2 wherein the means (310) is configured to generate the control signal in accordance with a combination of a band edge component maximisation technique carried out on the sampled VSB signal and the frequency spectrum transposed representation of the sampled VSB signal.

4. A symbol recovery apparatus according to claim 3, wherein the means (310) is configured to apply a weighting factor to either or both of the band edge component maximised sampled VSB or the frequency spectrum transposed representation of the sampled VSB signal

5. A symbol timing recovery apparatus used with a VSB-type receiver, the apparatus comprising:

an analog-to-digital converter (ADC) to receive a signal which is modulated by a vestigial side band (VSB) scheme and to digitalize the received signal using a predetermined sampling clock;

a multiplier to transit the digitalized VSB signal to a baseband;

a spectrum inverter to invert a spectrum by exchanging upper and lower frequency bands of the baseband VSB signal received from the multiplier;

a lower band edge component maximization (BECM) to perform a BECM algorithm with respect to the inverted baseband VSB signal, thereby generating lower error information which is the information on the error between a symbol phase of the received VSB-modulated signal and a preset reference symbol phase;

a loop filter to filter the lower error information of the lower BECM to output a lower band signal; and

a numerically controlled oscillator (NCO) to change a predetermined sampling clock according to the lower band signal from the loop filter.

6. The symbol timing recovery apparatus of claim 5, further comprising:

an upper BECM to perform the BECM algorithm directly with respect to the baseband VSB signal received from the multiplier, thereby generating upper error information which is the information on the error between a symbol phase of the received VSB-modulated signal and a preset reference symbol phase; and

a combiner to multiply the upper and the lower error information of the upper and the lower BECMs by predetermined weights, respectively, and to output to the loop filter final error information obtained by adding the multiplied val-

ues.

7. The symbol timing recovery apparatus of claim 6, wherein the BECM algorithm is a Gardener algorithm.

8. The symbol timing recovery apparatus of claim 6, wherein the upper BECM generates harmonic components of the upper frequency band signal from the frequency VSB signal and extracts symbol tone among the plurality of generated harmonic components, the symbol tone having the same phase as the symbol tone with a preset reference symbol phase, and then compares the symbol tone with a preset reference symbol phase to output upper error information of the symbol phase.

9. The symbol timing recovery apparatus of claim 6, wherein the inverter deletes a pilot signal from the baseband VSB signal before inverting the frequency spectrum.

10. The symbol timing recovery apparatus of claim 6, wherein the predetermined weights vary according to reliability of the upper and the lower error information according to a channel state.

11. The symbol timing recovery apparatus of claim 10, wherein the weights are determined by a size of the signals input to the upper and lower BECMs.

12. The symbol timing recovery apparatus of claim 5, wherein the spectrum inverter detects and deletes a pilot signal of the VSB signal before inverting the spectrum.

13. The symbol timing recovery apparatus of claim 5, further comprising a matched filter provided in front of the spectrum inverter to filter off the baseband VSB signal to increase signal-to-noise ratio.

14. The symbol timing recovery apparatus of claim 5, wherein the VSB-modulated signal is an American digital broadcasting signal of an advanced television system committee (ATSC) standard.

15. A receiver which receives a VSB-modulated signal by performing symbol timing recovery of a received VSB signal using a symbol timing recovery apparatus for a VSB-type receiver, as cited in claim 1.

16. A method of symbol timing recovery for a VSB-type receiver, the method comprising:

receiving a VSB-modulated signal and digitalizing the signal using a predetermined sampling clock;

transiting the digitalized VSB signal to a base-

band; inverting a spectrum by exchanging upper and lower frequency bands of the baseband VSB signal;
 generating lower error information which is the information on the error between a symbol phase of the received signal and a preset reference symbol phase, by performing a BECM algorithm with respect to the spectrum-inverted signal; and
 changing the predetermined sampling clock according to the lower error information.

17. The method of claim 16, further comprising:

performing the BECM algorithm directly with respect to the baseband VSB signal in the transiting operation, thereby generating upper error information which is the information on the error between a symbol phase of the received VSB-modulated signal and a preset reference symbol phase; and
 multiplying the upper and the lower error information by predetermined weights, respectively, and outputting final error information obtained by adding the multiplied values to the sampling clock changing operation.

18. The method of claim 17, wherein the predetermined weights vary according to reliability of the upper and the lower error information according to a channel state.

19. The method of claim 16, wherein the inverting operation detects and deletes a pilot signal of the VSB signal before inverting the spectrum.

20. The method of claim 16, further comprising filtering off the baseband VSB signal before the inverting operation to increase signal-to-noise ratio.

21. A symbol timing recovery apparatus used with a VSB-type receiver, the apparatus comprising:

a multiplier to transit a digitalized signal modulated by a vestigial side band (VSB) scheme signal to a baseband; and
 a timing recovery unit to invert a spectrum by exchanging upper and lower frequency bands of the baseband VSB signal received from the multiplier, to perform a lower band edge component maximization (BECM) algorithm with respect to the inverted baseband VSB signal, thereby generating lower error information which is the information on the error between a symbol phase of the received VSB-modulated signal and a preset reference symbol phase, to filter the lower error information of the lower BECM to output a lower band signal, and to

change a predetermined sampling clock according to the lower band signal from the loop filter.

22. The symbol timing recovery apparatus of claim 21, wherein the timing recovery unit comprises:

a spectrum inverter to invert the spectrum by exchanging upper and lower frequency bands of the baseband VSB signal received from the multiplier;
 a lower BECM to perform the lower band edge component maximization (BECM) algorithm with respect to the inverted baseband VSB signal;
 a loop filter to filter the lower error information of the lower BECM; and
 a numerically controlled oscillator (NCO) to change the predetermined sampling clock according to the lower band signal from the loop filter.

23. The symbol timing recover apparatus of claim 22, wherein the timing recover unit further comprises:

an upper BECM to perform the BECM algorithm directly with respect to the baseband VSB signal received from the multiplier, thereby generating upper error information which is the information on the error between a symbol phase of the received VSB-modulated signal and a preset reference symbol phase; and
 a combiner to multiply the upper and the lower error information of the upper and the lower BECMs by predetermined weights, respectively, and to output to the loop filter final error information obtained by adding the multiplied values.

24. A method of symbol timing recovery for a VSB-type receiver, the method comprising:

transiting a digitalized VSB-modulated signal to a baseband;
 inverting a spectrum by exchanging upper and lower frequency bands of the baseband VSB signal;
 detecting error information of respective symbol clocks from the baseband VSB signals of the lower frequency band and the upper frequency band; and
 combining the error information detected to perform symbol timing recovery.

FIG. 1

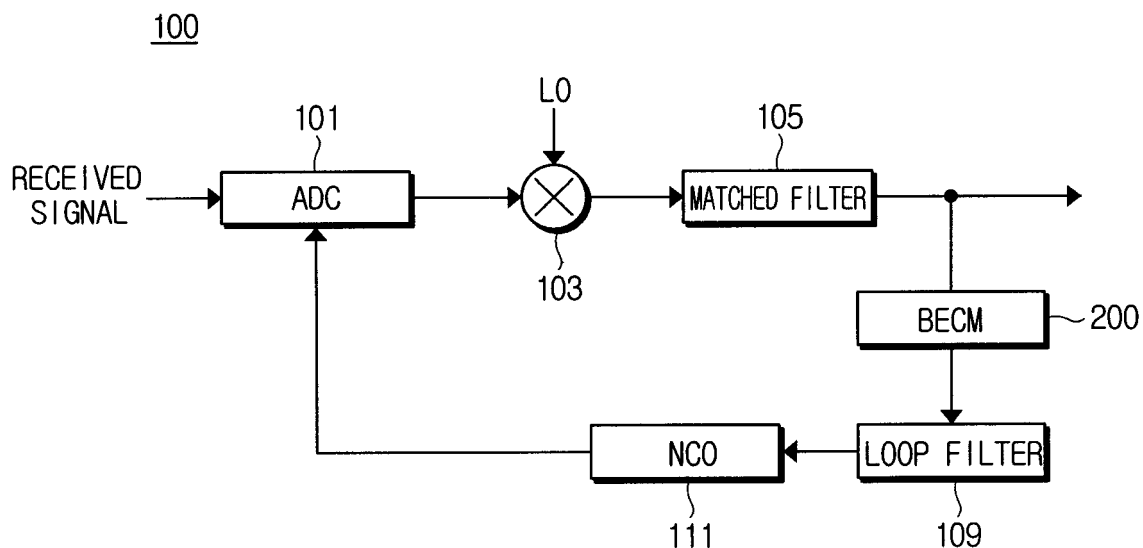


FIG. 2

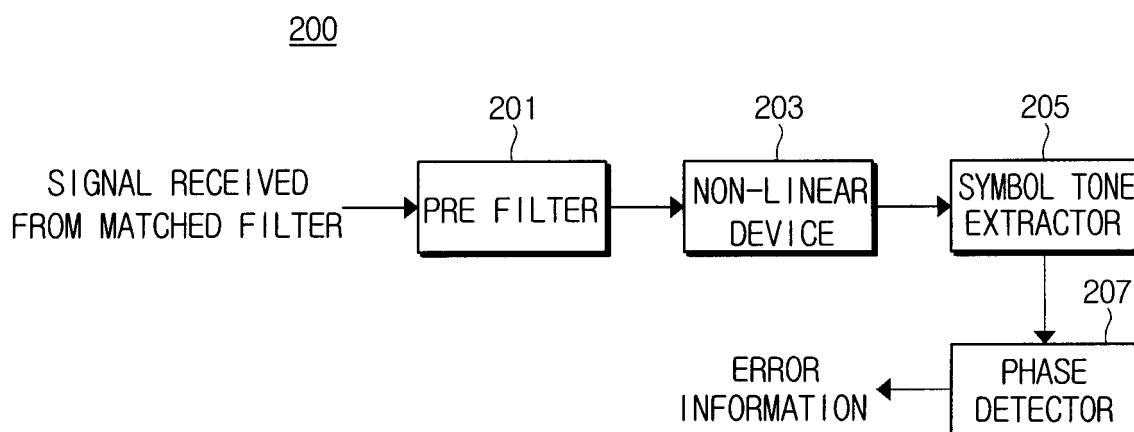


FIG. 3

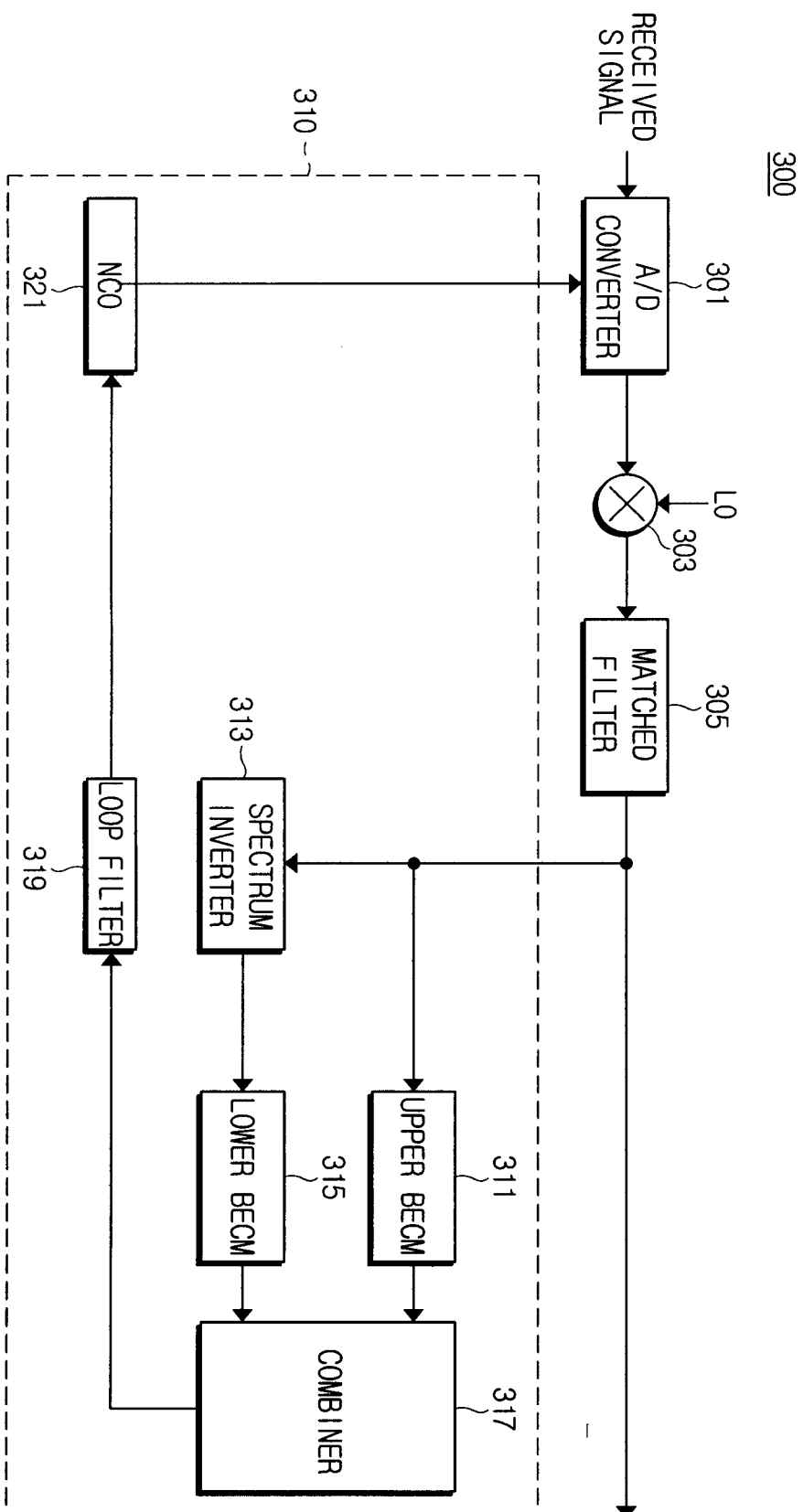


FIG. 4

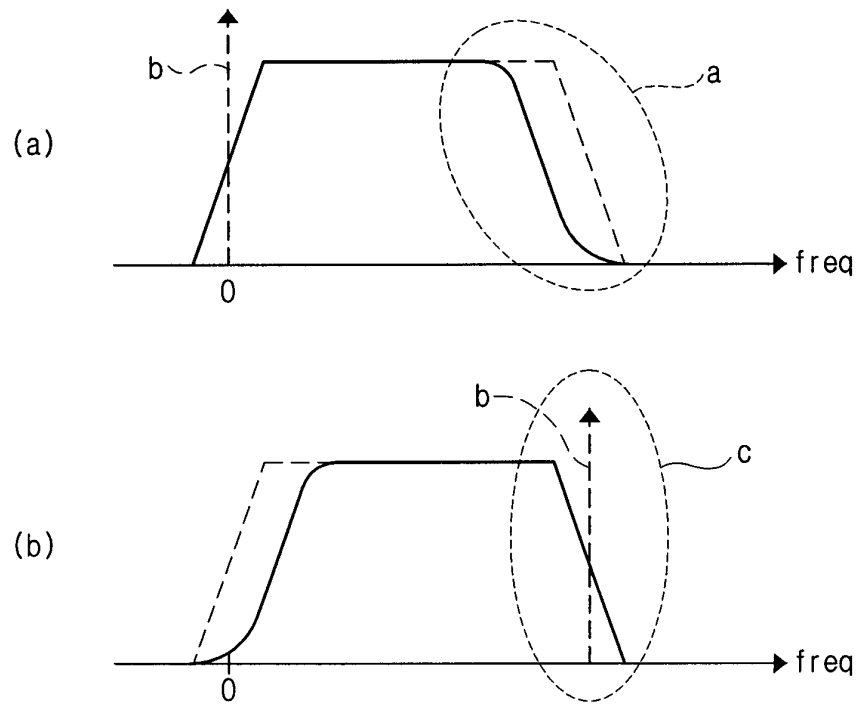


FIG. 5

